

**Naval Undersea Warfare Center Division
Newport, Rhode Island**

**SOFT IMPACT LOCATION CAPABILITY (SILC):
MODELING BLIND-LOADED AND PLUGGED IMPACTS AND
TIMING STATISTICS FOR THE POLYPHASE IMPACT DETECTION ALGORITHM**

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ABSTRACT

This technical memo describes two milestones related to the ongoing development of a digital signal-processing (DSP) algorithm to detect and time-tag impacts: (1) the capability to generate synthetic blind-loaded and plugged (BL&P) impacts for testing and (2) timing accuracy statistics from the candidate DSP algorithm using the synthetic BL&P impacts as inputs.

ADMINISTRATIVE INFORMATION

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LIST OF ABBREVIATIONS AND ACRONYMS

BL&P	Blind-loaded and plugged
DSP	Digital signal processing
Hz	Hertz
NUWC	Naval Undersea Warfare Center
SILC	Soft Impact Location Capability
SNR	Signal-to-noise ratio

INTRODUCTION

An important part of the Soft Impact Location Capability (SILC) program is the development of a digital signal-processing (DSP) algorithm that can detect and time-tag munition impacts on the surface of the ocean. Two milestones related to this effort are presented in this technical memo: (1) the capability to generate synthetic blind-loaded and plugged (BL&P) impacts for testing and (2) timing accuracy statistics from the candidate DSP algorithm using the synthetic BL&P impacts as inputs.

MODELING BL&P IMPACTS

Because of the small number of actual recorded BL&P impacts, it is necessary to generate realistic, controllable synthetic BL&P impacts for use in the MATLAB statistical characterization of the candidate DSP algorithm. To obtain signal parameters for the generation of synthetic BL&P impacts, actual signatures of BL&P impacts recorded off the coast of North Carolina in 2000 were examined. A typical impact is shown in figure 1. The signal shown is the signal as it is received at a hydrophone; it is not equivalent to the signal at the point of impact on the surface. The impact duration is approximately 250 msec, which is typical for the signatures in this recorded data set. The noise before and after the impact has been eliminated for plotting purposes. These impact data are sampled at a rate of 48,000 samples per second.

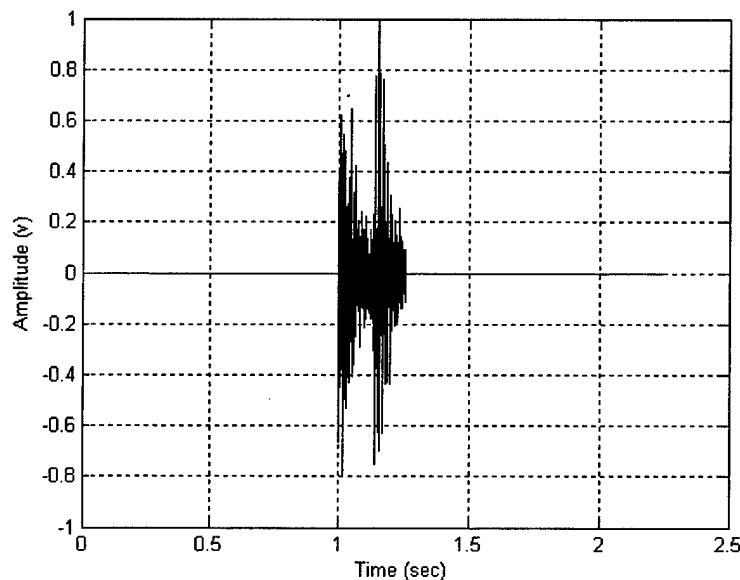


Figure 1. Actual BL&P Impact Starting at Time = 1 Second

Information from both the time and frequency domains (figure 2) was extracted from the real BL&P impact for use in the MATLAB modeling software. Figure 3 shows how this information is used to manipulate white Gaussian noise samples into synthetic impact signals. These synthetic impacts emulate both the time- and frequency-domain characteristics of a real impact.

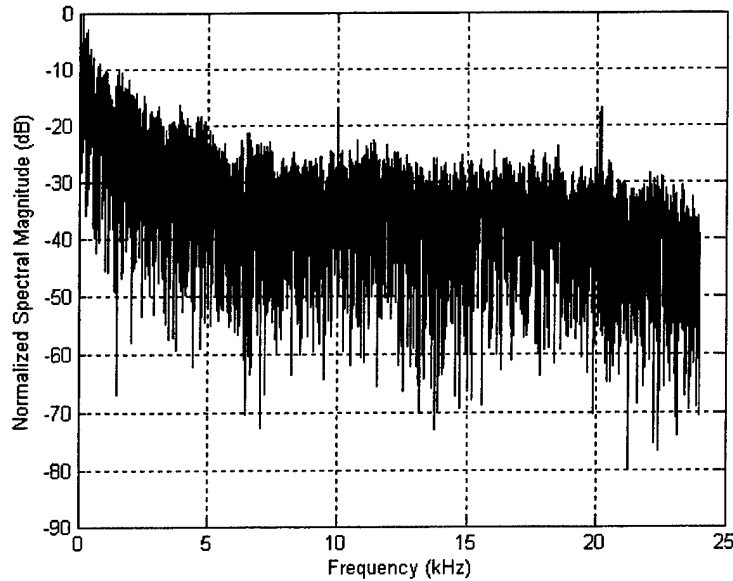


Figure 2. Normalized Spectrum for a Real BL&P Impact

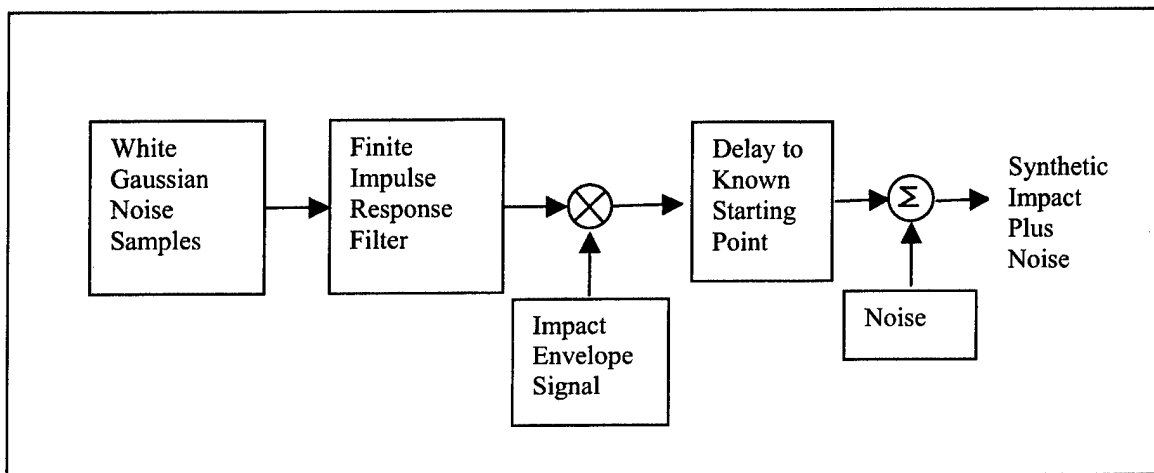


Figure 3. Block Diagram of Synthetic Impact Generation Process

The noise samples are filtered and then multiplied by a time-domain impact envelope signal. At this point, the signal is a synthetic impact starting at time = 0 seconds. The impact is then delayed in time to a random, known start time. Because the average power of the synthetic impact is controllable, noise is added to the impact, and the result is an impact that starts at a known time at a specified signal-to-noise ratio (SNR). Figures 4 and 5 show examples of synthetic impacts at SNRs of 5 dB and 15 dB, respectively.

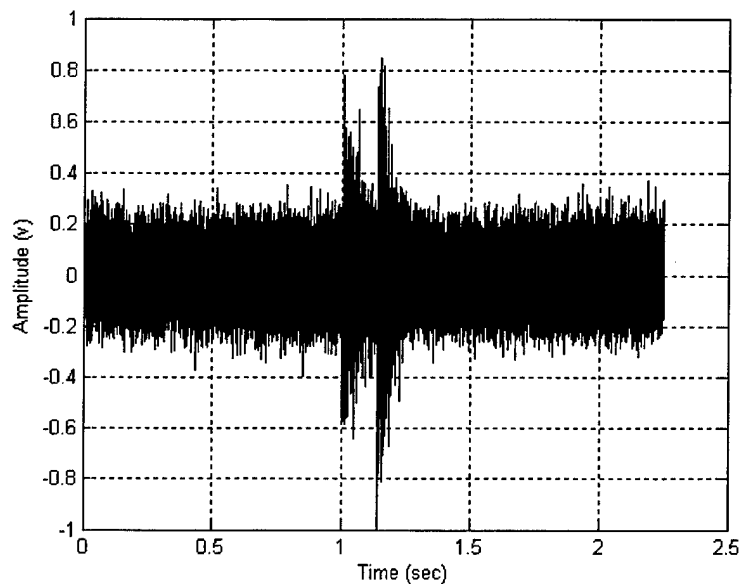


Figure 4. Synthetic Impact at SNR = 5 dB Starting at Time = 1 Second

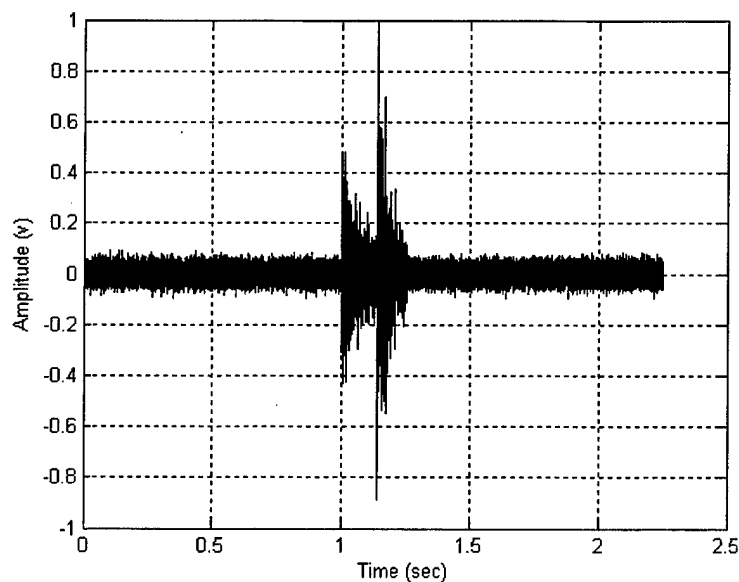


Figure 5. Synthetic Impact at SNR = 15 dB Starting at Time = 1 Second

POLYPHASE DETECTION AND TIME-TAG ALGORITHM

A candidate DSP algorithm that processes hydrophone data to determine whether an impact occurred ("detection") and at what time the impact occurred ("time-tag") has been developed and is referred to as the "polyphase impact detection algorithm." A simplified polyphase algorithm block diagram is shown in figure 6.

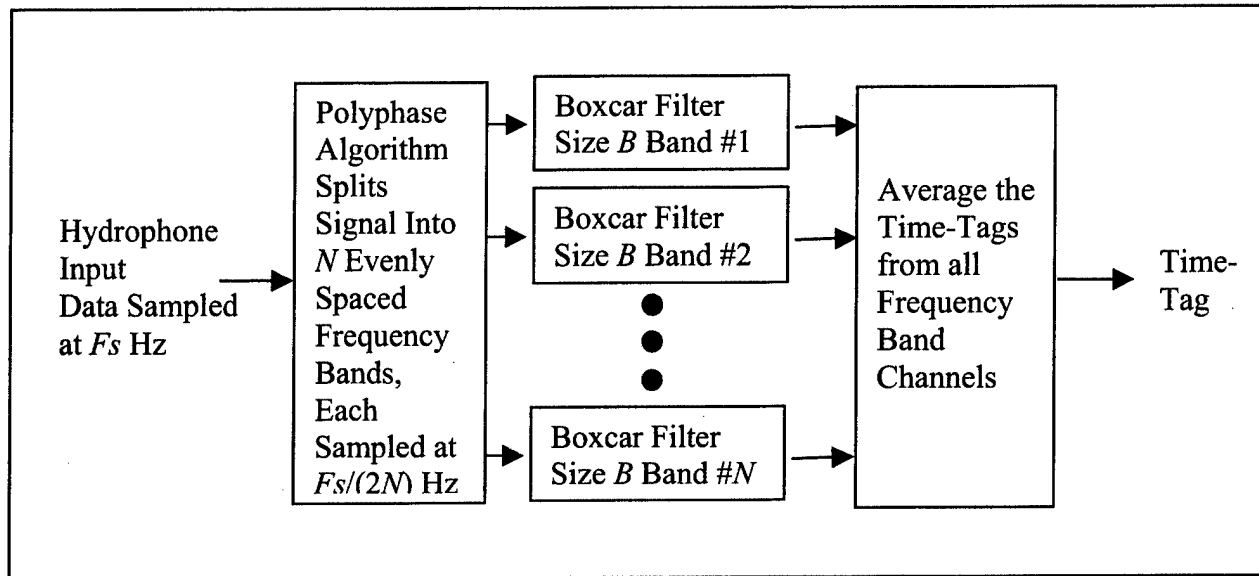


Figure 6. Polyphase Algorithm Block Diagram

The polyphase algorithm splits input hydrophone data sampled at F_s Hz into N evenly spaced decimated frequency band channels, each sampled at $F_s/(2N)$ Hz. A "boxcar" filter of length B is then used to integrate the signal to measure energy and calculate a time-tag. Each frequency channel is processed separately, and the time-tags from multiple frequency channels are averaged to produce a single time-tag for the detected impact.

Two key polyphase algorithm parameters are the number of frequency channels N and the length of the boxcar integration filter B . Each parameter affects performance; the primary focus is to determine how these two parameters affect time-tag statistics.

TIMING STATISTICS

To generate time-tag statistics, MATLAB software was developed to allow synthetic BL&P impacts at known SNRs to be input to the polyphase algorithm. Two polyphase parameters are varied: (1) the number of frequency channels N and (2) the length of the boxcar filter B . Figure 7 is a block diagram of this simulation software.

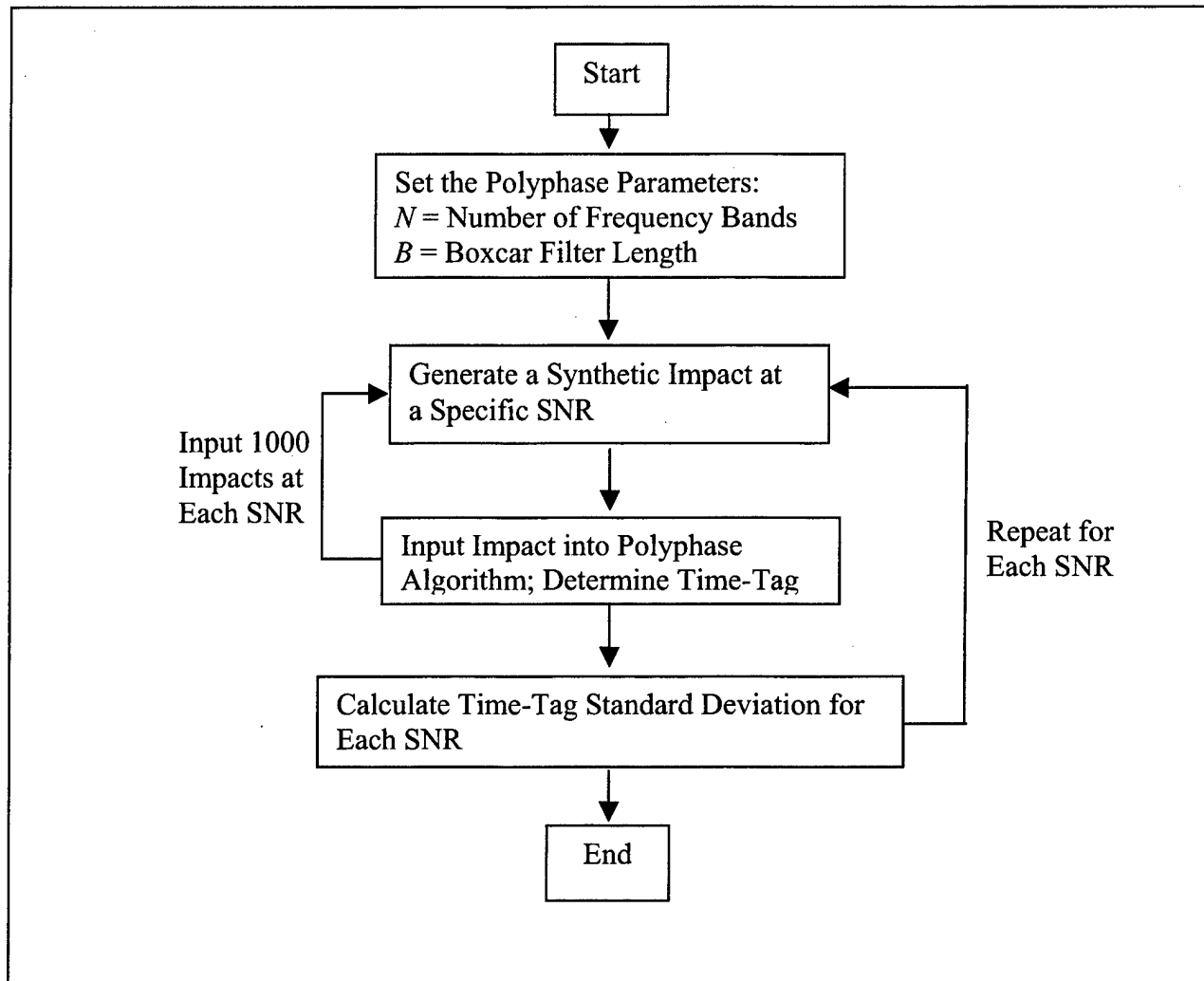


Figure 7. MATLAB Time-Tag Statistics Software Block Diagram

The result of this software is the time-tag standard deviation versus SNR for a given (N , B) polyphase algorithm parameter combination.

Based on previous tracking accuracy analysis, the time-tag standard deviation from the DSP algorithm must not exceed 0.5 msec; therefore, tests were performed at various (N , B) parameter combinations to determine timing performance regarding this 0.5-msec requirement.

Figure 8 displays timing results for a boxcar filter size $B = 50$ msec at an assorted number of frequency bands N ranging from 2 to 12. Timing performance remains quite consistent at all frequency band values. Depending on the number of frequency bands, an SNR of at least 7 to 9 dB is required to keep the timing standard deviation below 0.5 msec.

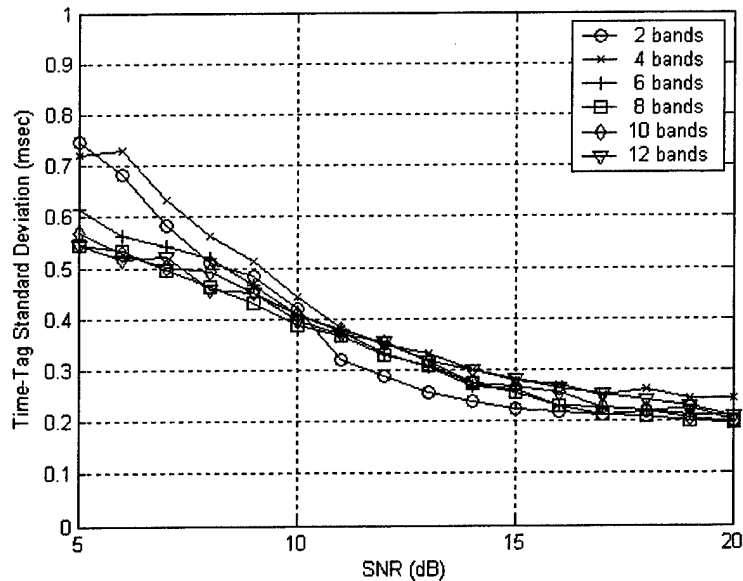


Figure 8. Time-Tag Statistics for a Boxcar Size of 50 Milliseconds

The timing results produced by keeping the number of frequency bands constant ($N = 6$) while varying the boxcar parameter B are shown in figure 9. Timing performance was best and quite consistent at boxcar values $B = 50, 100$, and 200 msec. When B was changed to other values ($150, 250$, and 300 msec), the time-tag standard deviation was above the desired value of 0.5 msec over the entire range of SNRs. Because the boxcar size parameter has a definite effect on performance, additional testing and analysis will be performed to determine the optimal boxcar value. Figure 10 shows a subset of these same results using a different scale on the vertical axis.

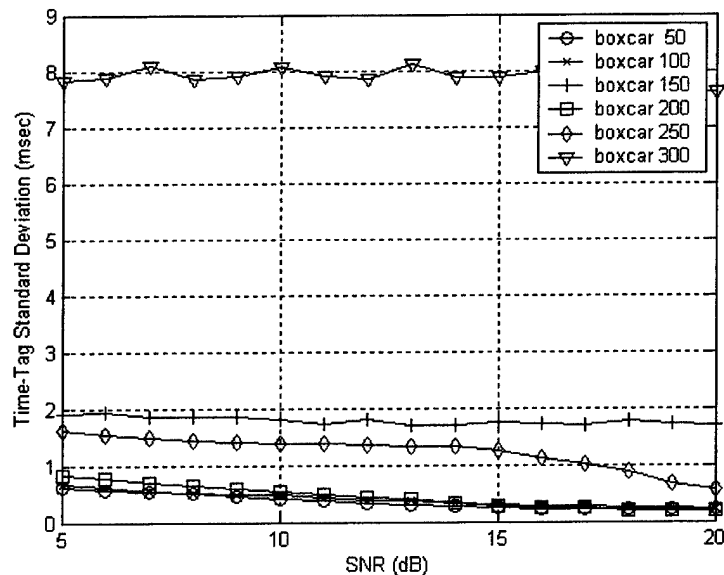


Figure 9. Time-Tag Statistics for Six Frequency Bands at Assorted Boxcar Values

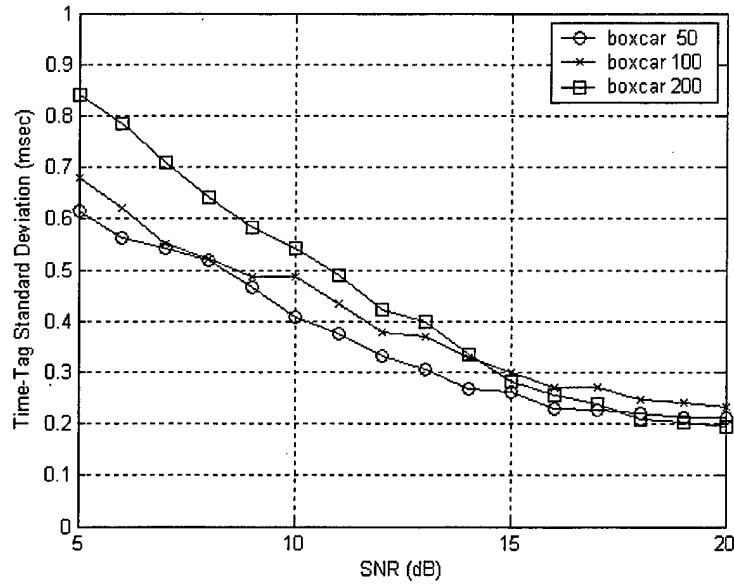


Figure 10. Time-Tag Statistics for Six Frequency Bands

Note that the time-tag statistics presented are a measure of algorithm performance when an impact is detected. Probability-of-detection and false-alarm-rate statistics, which may turn out to affect overall system performance, were not investigated.

CONCLUSIONS

Actual recorded impacts have been analyzed. Software has been written to create synthetic impacts that closely resemble real impacts in both the time and frequency domains. A preliminary polyphase DSP algorithm has been designed and developed in MATLAB. Statistics using synthetic impacts at user-controlled SNR values have been measured to determine the polyphase algorithm time-tag statistical performance for assorted combinations of algorithm parameters. Preliminary results indicate that a boxcar value B of approximately 50 msec yields the best performance. The number of frequency bands N does not have a significant effect on performance.

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